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- Surface coated cutting tool
- (Object)

The invention relates to a cutting tool whose surface is coated with a composite hard layer formed by means of chemical vapor deposition and having excellent wear resistance and chipping resistance.

(Construction)

A cutting tool consists substantially of a substrate whose surface is coated with a composite hard layer consisting substantially of an inner layer including one or more layers of titanium carbide, titanium nitride, titanium carbonitride, titanium carbonitride, and an outer layer including at least one alumina layer. The alumina layer contains so much κ -type alumina that an X-ray intensity ratio I_A/I_B of two specific crystal faces A and B in X-ray diffraction is not smaller than 2, where the A-face and B-face denote faces of κ -type alumina defined as those whose interfacial distances are 2.79Å and 2.57Å in ASTM4-0878, and I_A and I_B denote X-ray intensity of the faces A and B in X-ray diffraction.

DETAILED DESCRIPTION OF THE INVENTION

[Field of industrial application]

The present invention relates to a surface coated cutting tool having excellent wear resistance and chipping resistance, the cutting tool including a cemented carbide substrate whose surface is coated with a composite hard layer formed by means of chemical vapor deposition, the composite hard layer consisting substantially of an inner layer including one or more layers of titanium carbide, titanium nitride, titanium carboxide, and titanium oxicarbonitride (hereinafter referred to generally as titanium compound layers), and an outer layer including at least one alumina layer.

[Prior art]

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For the purpose of continuous and interrupted cutting of steel, it has been well known practice to use a surface coated cutting tool including a cemented carbide substrate whose surface is coated with a composite hard layer formed by means of chemical vapor deposition, the composite hard layer consisting substantially of an inner layer including a titanium compound layer and an outer layer including at least one alumina layer.

The alumina layer is chemically stable and displays excellent face wear resistance, but it adheres poorly to the substrate and lacks toughness. Thus, the surface of the cemented carbide substrate is coated first with a titanium compound layer formed by means of chemical vapor deposition, then an alumina layer is formed on the titanium compound layer by means of chemical vapor deposition, thereby giving wear resistance and toughness to the formed composite hard layer to improve chipping resistance.

For the purpose of forming the alumina layer of the composite hard layer by means of chemical vapor deposition, a method is known for speeding up the growth rate of the alumina layer by using a reaction gas obtained by adding 0.01 to 1.0 vol % of hydrogen sulfide gas to the normal reaction gas.

The use of this method shortens the time during which the inner layer made of titanium compound and the cemented carbide substrate are held at high temperature, with the result that the structure of the inner layer and the substrate is unlikely to change. Thus, it is said that a surface coated cutting tool having a better performance than the conventional tools can be obtained according to this method (refer to, for example, Japanese Examined Patent Publication 62-3234).

The alumina layer obtained by using a reaction gas containing 0.01 to 1.0 vol % of hydrogen sulfide gas is mainly an α -type alumina layer. It is also known that a x-type alumina layer is obtainable by changing the volume of carbon dioxide gas in the reaction oas.

[Problems to be solved by the invention]

In recent years, there has been an increasing demand for a labor-saving and more rapid cutting operation. This demand strongly requires a high speed in continuous and interrupted cutting operation, that is both high speed feeding and high speed cutting under more severe conditions. During the high speed cutting operation, the temperature of the cutting edge rises above 1000 °C and steel chips of exceedingly high temperature pass along the face of the cutting tool, which accelerates wear of the face. Thus, the cutting tool is chipped or damaged at a relatively early stage. Under these severe conditions, the cutting tools coated with the composite hard layer including the conventional alumina layer have a relatively short lifetime because the coated layer has insufficient wear resistance and chipping resistance.

[Means for solving the problem]

In view of the above, the inventors of the present invention carried out a research to develop a cutting tool whose surface is coated with a composite hard layer including an alumina layer having better wear resistance and chipping resistance than the prior art and obtained the following results.

A cutting tool comprising a substrate whose surface is coated with a composite hard layer consisting substantially of an inner layer including one or more layers of titanium compounds, and an outer layer including at least one alumina layer containing so much x-type alumina that an X-ray intensity ratio of two specific crystal faces in X-ray diffraction is not smaller than 2, has better wear resistance and chipping resistance than the conventional cutting tools coated with a composite hard layer including the conventional alumina layer.

The invention was developed on the basis of these research results and is directed to:

a cutting tool comprising a substrate whose surface is coated with a composite hard layer including an inner layer having one or more layers of titanium carbide, titanium nitride, titanium carbonitride, titanium carboxide, and titanium oxicarbonitride, and an outer layer having at least one alumina layer, wherein the alumina layer contains so much κ -type alumina that an X-ray intensity ratio I_A/I_B of two specific crystal faces A and B in X-ray diffraction is not smaller than 2, where the A-face and B-face denote faces of κ -type alumina defined as those whose interfacial distances are 2.79Å and 2.57Å in ASTM4-0878, and I_A and I_B denote X-ray intensities of the faces A and B in X-ray diffraction.

The reason why the cutting tool according to the invention has better wear resistance and better chipping resistance compared with the conventional tools is thought to be that abnormal damage caused by friction between steel chips and the tool is unlikely to occur because x-type alumina, demonstrating orientation to the face A, makes the surface of the coated laver smooth.

Thus, when the alumina layer contains so much special x-type alumina that the ratio of X-ray intensity I_A of the face A to that I_B of the face B in X-ray diffraction is not smaller than 2, i.e., $I_A/I_B \ge 2$, wear resistance and chipping resistance are further improved. Thus, the cutting tool whose surface is coated with the composite hard layer including this alumina layer has a longer lifetime even under severe working conditions such as high speed cutting.

Besides special x-type crystals whose X-ray intensity ratio (I_A/I_B) is not smaller than 2, the alumina layer according to the invention may contain alumina having a different crystallo-graphic structure. However, it is desirable that the amount of special x-type crystals in the alumina layer be at least not less than 30 %, preferably not less than 50 %, and most preferably not less than 70 %. The percentage of special x-type crystals is obtained from the following equation:

Percentage of special κ-type crystals =

sum of counts of all the peaks of $\kappa \cdot \text{Al}_2\text{O}_3$ in X-ray diffraction

× 100

sum of counts of all the peaks of Al_2O_3 in X-ray diffraction

It is not necessary for the alumina layer to be an outer-most layer. At least one layer of titanium compound may be formed on the alumina layer.

A method for forming the inventive alumina layer containing special x-type crystals whose peak intensity ratio (I_A/I_B) is not smaller than 2 is as follows.

During an alumina coating reaction, a substrate coated with titanium compounds is held in a mixed gas containing no CO₂ gas, but AlCl₃, H₂ and, if necessary, HCl for a predetermined time in the first step, and is subsequently caused to react in a mixed gas containing CO₂, AlCl₃, H₂ and, if necessary, HCl in the second step.

It will be appreciated that the mixed gas used for the coating reaction may further contain H_2S if necessary.

The conditions for the alumina coating reaction are described in detail below:

First Step -

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Temp.: 800 to 1050 °C , Time: 1 to 120 min.

Gas Composition : 0.5 to 20 vol % of AlCl $_3$, 0 to 20 vol % of HCl, remainder H $_2$

Second Step -

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Temp.: 800 to 1050 °C

Gas Composition : 0.5 to 30 vol % of CO_2 , 0.5 to 20 vol % of $AlCl_3$, 0 to 20 vol % of HCl, remainder H_2 If necessary, 0.01 to 5 vol % of H_2S may be added at the beginning or in the middle of the second step. The composition of the mixed gas may be changed continuously during the transition from the first step to the second step.

[Example]

The surface coated cutting tool according to the invention will be described in more detail by way of an example.

A mixed powder having the composition: 87%WC-2%TiC-1%TiN-4%TaC-6%Co was prepared according to a normal method. The mixed powder prepared in this way was compressed into a green compact, which was then sintered at a temperature of 1410° in vacuum for 1 hour. In this way, a cemented carbide substrate A of the form of ISO SNMG120408 was prepared.

Similarly, a mixed powder having the composition: 82%WC-5%TiC-5%TaC-8%Co was prepared according to a normal method. The mixed powder prepared in this way was compressed into a green compact, which was then sintered at a temperature of 1380° in vacuum for 1 hour. In this way, a cemented carbide substrate B of the form of ISO SNMG120408 was prepared.

On the surface of the cemented carbide substrate A, there was a tough surface layer of a thickness of 20 μ m including substantially no hard disperse phase (Ti, Ta, W) (C, N) and having a Co-amount increased to a maximum of 1.8 times greater than the internal Co-amount. On the other hand, there was almost no difference in structure between the surface and internal portions of the cemented carbide substrate B.

Honing of as large as 0.05R (R is the radius of the edge of the cutting tool in mm) was applied to the cutting edges of the thus obtained cemented carbide substrates A and B, and the surfaces of the substrates were washed. The inventive surface coated cutting tools 1 to 8 were manufactured by coating the surface of the substrate A under the conditions specified in TABLE-1 to TABLE-7 and by coating the surface of the substrate B under the conditions specified in TABLE-8. For the purpose of comparison, the conventional surface coated cutting tools 1 to 8 were manufactured by coating the surface of the substrate A under the conditions specified in TABLE-9 to TABLE-15 and by coating the surface of the substrate B under the conditions specified in TABLE-16.

X-ray diffraction was conducted for the inventive cutting tools 1 to 8 and the conventional cutting tools 1 to 8 to measure the X-ray intensity ratio I_A/I_B . The measurement results are shown in TABLE-17.

Further, a continuous cutting test and an interrupted cutting test were conducted for the above cutting tools under the following conditions. A wear width on the flank face was measured in the former test, whereas the lapse of time until chipping was measured in the latter test. The measurement results in the respective tests are again shown in TABLE-17.

[Cutting Test Conditions]

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- Continuous C	utting -
Work piece Cutting speed Feed rate Cutting depth Cutting time Coolant	JIS SCM440 (hardness : H _B 220) round bar 250 m/min. 0.3 mm/rev. 1.5 mm 20 min. none

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- Interrupted Cut	ting -
Work piece JIS Cutting speed Feed rate Cutting depth Cutting time Coolant	SNCM439 (hardness: H _B 280) rectangular bar 100 m/min. 0.236 mm/rev. 3.0 mm 30 min. none

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TABLE-18, the ASTM table, defines faces by means of face index [indicated in (h, k, l)], but the specific faces of this x-Al₂O₃ are not yet identified. "Face A" and "face B" have been written in a blank column of this table in order to identify the faces. Fig. 1 is a graph showing X-ray diffraction data of the coating layer of the inventive cutting tool 5 in the example. I_A and I_B represent x-ray intensities of the faces A and B. A

theoretical d-value of the face A is 2.79 according to TABLE-18, but a measured d-value thereof is 2.812 which varies slightly from the theoretical d-value. The theoretical and measured d-values of the face B are 2.57 and 2.576, respectively. The horizontal axis of Fig. 1 represents 20 which is an angle (in degree) an X-ray makes in the X-ray diffraction. Numerical values (2.812, 2.576, etc.) written on the respective peaks in this graph denote an interfacial distance d (in Å).

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50				LAYER			lst		2nd	3rd	4.4	\neg	5th							

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5							н		REM.	REW		REM.	REM		inder)				
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10				(VOL #			8						100	\parallel	lenote				
				REACTION GAS COMPOSITION (VOL %)		132	ATCT,						3		(REM.				
15		1.	•	OMPOS		3	_	I			\dagger	н		\parallel					
		CONDITIONS		GAS C		ž	<u> </u>] =		32		52.							
20		Con		ACTION		CHICN	•			9.0									
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30		ION		TIME	(MIM)		1		-			1 5	222				Γ	$\left \cdot \right $	
35		REACTION		PRES -	(Torr)			120	05	7	100	50			Γ	-			
40			2440	TEMP.	(၁.)			006	900		1020	1000							
4E			THICK-	NESS	(m#)		,		6.0		n >	6.0			er	er	er	terial	
45			TYPE	ě O	LAYER		Tin		Tick	Ticho		A1203.		·· ··	3rd Layer	2nd Layer	18t Layer	Base Material	
50				LAYER			18t		2nd	3rd	7	4th //						-	
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20		COND		REACTION GAS COMPOSITION (VOL 8)		CH,CN				B .		T								
<i>2</i> 5	6 2			KEA		H.	7		\dagger	+		+	+							
23	TABLE-12			-		Ticl,	1	m	1 ~	+		-	+							
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		REACTION	TIME		(MIM)		1		_	1			\perp					\int	1	
35		REA	PRES-	SURE	(Torr)		135	770	50	5		20	300			Γ	$\left\{ \right]$			
40			REAC.	TEMP.	(၁.)		920		920	1000		1000	900							
			THICK-	NESS	(m#)		0.5	1	6.0	0.5		0.0	.5						ríal	
45		l	TYPE		LAYER		7	+			+	رد ا	°	╢.		3rd Layer	2nd Layer	1st Layer	Base Material	
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50				LAYER			18t		ZNG	3rd	4 t		Sth							
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15				REACTION GAS COMPOSITION (VOL %)		_	7	· ·			(REM			
			SNO	COMPC		3	-+	<u>-</u>	-	$-\parallel$				
20			SNOTITONS	IN GAS		z	-+	32		$-\parallel$				
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25	Table-13	.		2		Ħ.								
	TABL					Tic1,		۷					_	_
30		LON		TIME	(MIM)	<u> </u>	1	1	300			Γ	$\frac{1}{2}$	
35		REACTION		PRES- SURE	(Torr)		50		Oc.					
40				REAC. TEMP.	(D _e)		870	1020						
45				THICK-	(m#)		6.0	6.0			er	er	terial	
			9026		LAYER		Ticn	A1,0,			2nd Layer	1st Layer	Base Material	
50				LAYER			18t	2nd						

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15			•	REACTION GAS COMPOSITION (1) CT		_	co Alcı,	-			1	3	(REM.				
20			CONDITIONS	GAS COM		2	£		1	26	+						
				ACTION		GH, CA											
25 .	-14			2		8	1	6	I								
	TABLE-14					Ticl,		е	1-	າ						r	
30		NO.		TIME	(MIN)		1		1	1	300				ſ		
35		REACTION		PRES-	<u> </u>		0.5	3	50	1	50		Γ	$-\int$	1		
40		1		KEAC. TEMP.	(0.)		1020	1	1000	1	1000						
45			THICK	NESS	(mn)		3.0		3.0	2	2:5		į	j .	ir i	erial	
			TYPE		LAYER		Tic		LICN	A1,0,			3rd Laver	2nd Laver	1st Laver	Base Material	
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20		COND		REACTION GAS COMPOSITION (VOL %)		CH, CN													
25	ស			REJ		e e		o,	1,	+			\dashv						
	TABLE-15					ricı,		m	m										_
30		TION	TIME	a i	(MIM)		1			1 8	200						Γ	$\frac{1}{2}$	
35		REACTION	PRES-	SURE	(Torr)		S	3	20	50		300		[\int			
40			REAC.	TEMP.	(၁.)		1020		1000	990	1	006							
4 5			THICK-	NESS	(m //		3.0		3.0	6.0		0.0			er	er	er	terial	
-			TYPE	OF	- THE R		Tic		Tich	A1,0,	Z.			. .	3rd Layer	2nd Layer	1st Layer	Base Material	
50				LAYER			1st	+	ZIIG	3rd	4th	-1							
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15				REACTION GAS COMPOSITION (1701			Alcı.	,			9	100)	14 Y			
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20		CONDITIONS		GAS C	٠		ž		56	\perp						
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25	و			RE		. [Œ.		^							
	TABLE-16				•		ric1,		า							Г
30		FION		TIME		(MIM)		T		300					Γ	
35		REACTION		PRES-	SURE	(Torr)		50		20						
40			Okaa Okaa	VEAL.	TEMP.	(၁.)		1020		1000						
45			THICK-	, , , , , , , , , , , , , , , , , , ,	NESS	(m#)		5.0	1	6.0				er	er	terial
45			TYPE			LAYER		Tick		A1,0,			3 2	and Layer	1st Layer	Base Materi
50				AYER	_			st	T	D I						

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5		LAPSE OF TIME UNTIL CHIPPING IN INTER- RUPTED CUTTING TECT	(MIN.)	10.1	8.3	8.9	8.8	7.2	7.9	8.5		0.,	5.3	5.5	5.0	5.1	4.0	5.2	5.8	
15 20	TABLE-17	FLANK WEAR WIDTH (mm) AFTER 20 MIN. CONTINUOUS CUTTING	TEST	0.21	0.20	0.18	0.20	0.24	0.27	0.26	0.31	0.44	0.43	5 0	15:0	0.54	0.49	0.53	0.50	0 63
25 30	TABI	RATIO (%) WHERE I _A /I _{B ≥ 2}	30	65	200	007	001	700	05	90	100	0 *	0	0	0	c			0)	0
35		I _A /I _B	80	7	30	25	12	9	ď	,	7	0.7	0.7	6.0	6.0	0.2	0.6	0.5	0.7	
40		ORY	1	2	3	4	S	9	7	8		1,		M	4	5	9	7	8	
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* This ratio is set to 0 since the conventional surface coated cutting tools contain no special κ -type Al_2O_3 of $I_A/I_B \approx 2$, though containing normal κ -type Al_2O_3 of $I_A/I_B \approx 2$.

55 [Effect of the invention]

As is clear from the results shown in TABLE-17, the value of I_A/I_B of x-type alumina of any of the inventive cutting tools 1 to 8 is not smaller than 2. On the contrary, the value of I_A/I_B of x-type alumina of

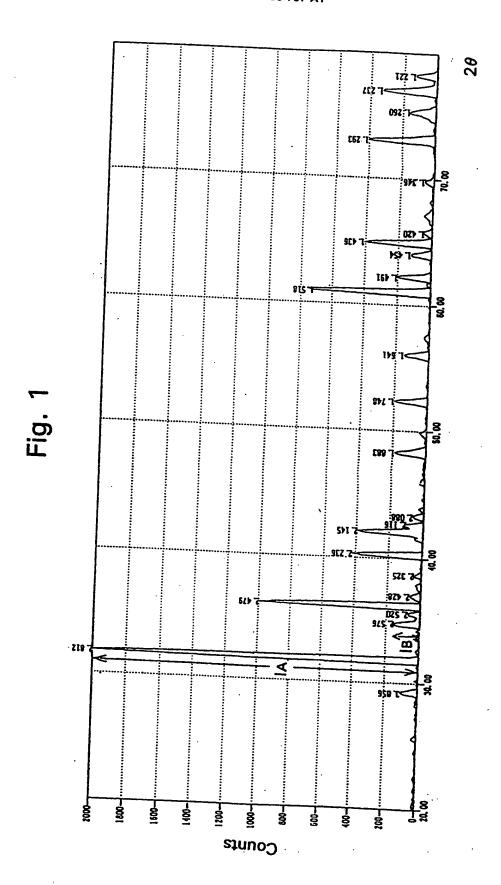
any of the conventional cutting tools 1 to 8 is smaller than 2. Further, any of the inventive cutting tools 1 to 8 demonstrates a smaller wear width on the flank face in the continuous cutting test and has a longer lapse of time until chipping in the interrupted cutting test, compared with the conventional cutting tools 1 to 8.

Thus, the surface coated cutting tool according to the invention has a better performance than the conventional tools, and the use thereof leads to a reduced frequency of replacement, thereby contributing Claims

- A cutting tool comprising a substrate whose surface is coated with a composite hard layer including an inner layer having one or more layers of titanium carbide, titanium nitride, titanium carbonitride, titanium carboxide, and titanium oxicarbonitride, and an outer layer having at least one alumina layer,
- wherein the alumina layer contains so much x-type alumina that an X-ray intensity ratio I_A/I_B of two specific crystal faces A and B in X-ray diffraction is not smaller than 2, where the faces A and B denote faces of x-type alumina defined as those whose interfacial distances are 2.79Å and 2.57Å in ASTM4-0878, and I_A and I_B denote X-ray intensities of the faces A and B in X-ray diffraction.
 - 2. A cutting tool according to claim 1, wherein the alumina layer contains at least 30 % of x-type alumina.
- 3. A cutting tool according to claim 2, wherein the alumina layer contains at least 50 % of x-type alumina.
 - 4. A cutting tool according to claim 3, wherein the alumina layer contains at least 70 % of x-type alumina.
- A cutting tool according to claim 1, wherein the alumina layer containing x-type alumina is the
- 6. A process for producing a cutting tool according to claim 1 by coating the surface of a substrate with a composite hard layer including an inner layer having one or more layers of titanium carbide, titanium nitride, titanium carbonitride, titanium carboxide, and titanium oxicarbonitride and an outer layer having at least one alumina layer, wherein the substrate coated with titanium compounds is held in a mixed gas containing no CO2 gas but AlCl3, H2 and, if necessary, HCl for a predetermined time in the first HCl in the second step so that an alumina layer containing CO2, AlCl3, H2 and, if necessary, intensity ratio Ia/IB of two specific crystal faces A and B in X-ray diffraction is not smaller than 2, is distances are 2.79Å and 2.57Å in ASTM4-0878 and IB denote X-ray intensities of the faces A and B in X-ray diffraction.
- 7. A process according to claim 6 characterized in that the mixed gas used for the coating reaction further contains H₂S.
 - 8. A process according to claim 6 characterized in that the conditions for the alumina coating reactions in the first step are a temperature of 800 to 1050 °C, a time of 1 to 120 minutes, a gas composition of 0.5 to 1050 °C and gas composition of 0.5 to 30 vol % of CO₂, 0.5 to 20 vol % of AlCl₃, 0 to 20 vol % of HCI, remainder H₂.
 - 9. A process according to claim 8 wherein 0.01 to 5 vol % of H₂S have been added at the beginning or in the middle of the second step.
 - 10. A process according to claim 8 wherein the composition of the mixed gas is changed continuously during the transition from the first step to the second step.

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EUROPEAN SEARCH REPORT

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